Λ DOUBLET RADIATION FROM OH EXCITED ROTATIONAL STATES

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I will briefly summarize some recent observational results on Λ doublet maser radiation from OH excited rotational states. Combination of these results with interferometric observations should enable us to distinguish between the variety of pumping models that have been proposed for the ground state OH masers. I will not discuss pumping models since the time is limited and you would not believe me anyway.

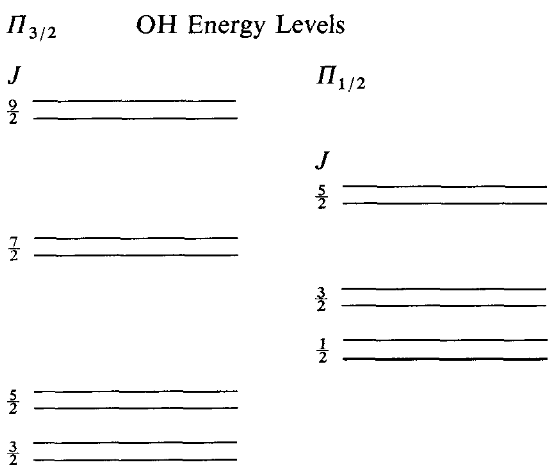

Fig. 1.

Figure 1 shows the energy levels of the OH molecule. The Λ doublet and rotational splittings are not to scale and the hyperfine splitting is not shown. The energy levels are divided into two ladders, the $\Pi_{3/2}$ and the $\Pi_{1/2}$, where the subscript is the sum of the electronic spin and orbital angular momentum. In the $\Pi_{3/2}$ ladder, besides the well known 18 cm emission from the ground state ($J=\frac{3}{2}$), maser radiation has also been observed at 5 cm from the $J=\frac{5}{2}$ state and at 2.3 cm from the $J=\frac{7}{2}$ state. Because the observed radiation is of the type $\Delta F=0$ the Λ doublets in the $\Pi_{3/2}$ ladder are probably inverted. On the other hand, searches for radiation from both the $J=\frac{1}{2}$ and $\frac{5}{2}$ states in the $\Pi_{1/2}$ ladder have failed to reveal anything. Although 6 cm radiation from the $\Pi_{1/2}$ $J=\frac{1}{2}$ state has been observed it is of the type $\Delta F=1$ which is associated with anomalies in the hyperfine populations rather than with an inversion of the Λ doublet as a whole. Therefore, the $\Pi_{1/2}$ ladder is probably not inverted (some inversion mechanisms, such as absorption of near infrared radiation, pump the $\Pi_{3/2}$ ladder much more rapidly than the $\Pi_{1/2}$ ladder).

De Jager (ed.), Highlights of Astronomy, 391–393.

Recently J. L. Yen, C. Gottlieb, P. Palmer and myself have carried out a fairly sensitive 5 cm survey of the $\Pi_{3/2}$ $J=\frac{5}{2}$ state with the NRAO 140 ft telescope. The data are not yet fully analyzed. Six sources were detected (W3, W75N, NGC 6334N, Sgr-B2, NML Cyg, W49) and an example of the quality of the spectra is shown in Figure 2. This is the $F=3\rightarrow3$ transition observed in the source W3 in right circular polarization. Like the ground state lines, these 5 cm lines are generally circularly polarized and quite narrow in almost all sources observed. In W 3 5 cm features are visable over most of the velocity range in which ground state features are observed

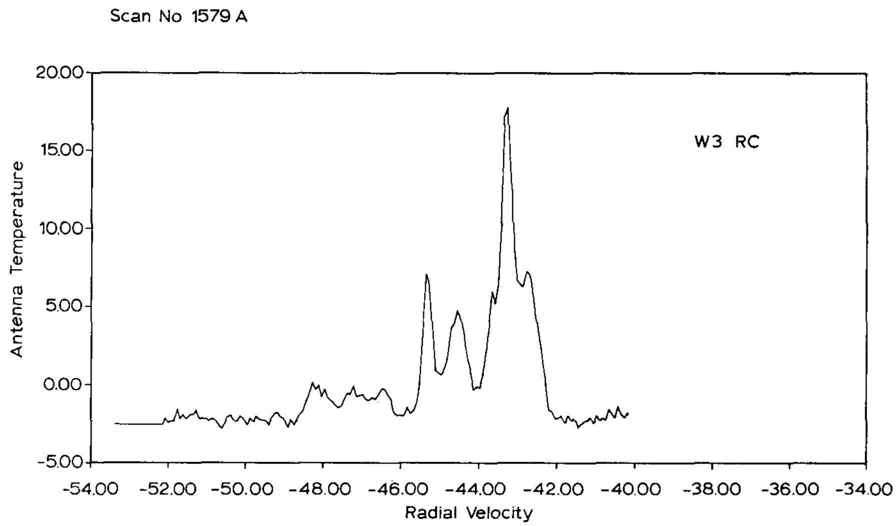

Fig. 2.

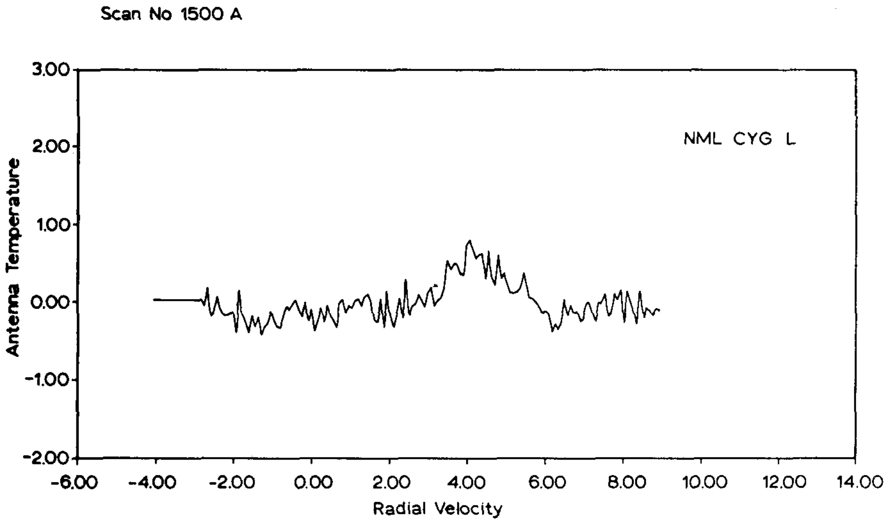

Fig. 3.

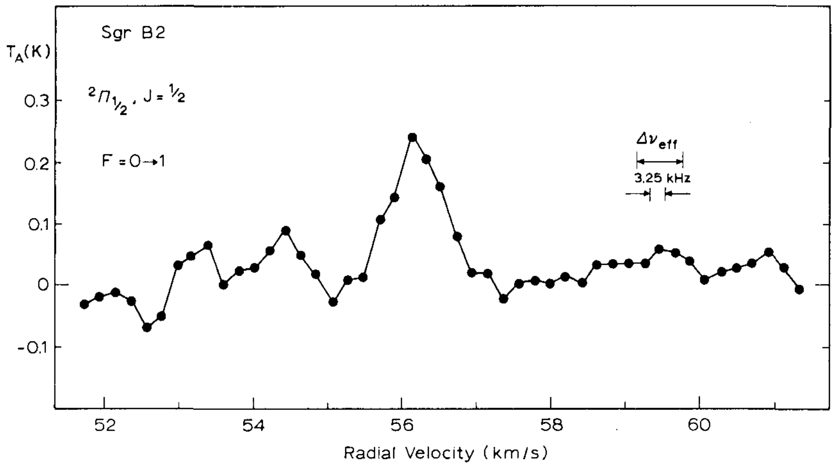

Fig. 4.

so much detailed comparison is possible. The excellent signal to noise also allows the possibility of VLBI observations of these lines. Such observations have already been attempted between the Onsala Space Observatory (Sweden) and the NRAO 140 ft and MIT Haystack telescopes. Results are not yet available but a comparison of the sizes and positions of ground and excited state OH and H_2O masers should be very interesting. Ultimately absolute positions should be attainable but even relative positions are of considerable interest.

Figure 3 shows an $F=3\rightarrow3$ spectrum of NML Cygnus obtained with a linearly polarized feed. This is the first and, at present, only excited state OH line observed from an infrared star. It is interesting to remember that the 1612 MHz ground state OH emission in this source is observed in two 'clumps' in velocity space separated by about 40 km/sec. The velocity of the observed 5 cm line falls between these two clumps where 18 cm emission is either very weak or non-existent. The velocity of the H_2O line observed in NML Cyg also does not agree with the 5 cm OH velocity.

Figure 4 is of a different OH excited state, the $\Pi_{1/2}$ $J=\frac{1}{2}$ state at 6 cm wavelength. Although a number of sources show detectable radiation in the $F=1\rightarrow0$ transition only Sgr B2 has an observable $F=0\rightarrow1$ line. This is rather peculiar since for all other ground and excited state lines W3 is, in general, the most intense source. When Dr. Palmer and I first observed this line we assumed it was attributable to OH. We still believe that it is very probably an OH line, primarily because of the very narrow linewidth. However, Sgr B2 is THE SOURCE in the Galaxy for finding new molecules. So although we are not ready to call the line mysterium we do point out the slight chance it is not OH. For example, a number of transitions in CH_3NH_2 have rest frequencies that agree, within the rather large laboratory error bars, with the most likely rest frequency of the observed line.